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Original Article

EXPERIMENTAL COMPARISON OF SOLAR PARABOLOID COLLECTOR WITH AND WITHOUT MIRROR IN ALUMINUM FOIL AS REFLECTORS

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ABSTRACT

In the present modernized world, energy is the major prerequisite without which man cannot survive one of the most important sources of energy is solar energy. Solar energy is very abundant and everlasting when compared to all other energies. With prices of LPG elevating, the method of using paraboloid solar collector proves to be cost- effective and energy conserving. By focusing sun rays to a point, a huge amount of energy is harnessed which can be used for many purposes. This is one of the methods to harness solar energy among many others like PV cells and other solar reflectors. In light of the facts like the PV cells are only 32% efficient there is immense need for improvement in the area. The various concentrating solar panels also have limitations like focusing on a line rather than a point. In this paper, paraboloid reflector is used as one of the most effective instruments in harnessing solar energy. As the role of a reflector is the most important in a paraboloid concentrator, the major attention will be focused on it. Aluminum foil with and without the combination of mirrors, the difference is established and tabulated. A collector is located at Kurnool (Latitude 15.83^{o}N, Longitude 78.05^{o}E) Andhra Pradesh.

KEYWORDS: Aluminum Foil, Mirrors, Reflector & Paraboloid Collector

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INTRODUCTION

Solar energy is the major source of energy available naturally. In present- day energy is required for the development of any nation. Basically, sources of energy are classified into two categories, renewable energy and non-renewable energy sources. Of these renewable energy sources can be obtained from natural sources such as solar energy, wind energy, tidal energy etc. whereas non- renewable energy source energy once used cannot be reused such as petroleum products oil, natural gas, and coal etc [1-5].

Fossil fuels will be degraded for the next few decades their serious requirement for the alternate energy source. The solar energy among the available renewable sources plays a major role to convert into the useful form. However ,solar energy obtained on the hottest part of earth exceeds 1kw/m^2. So large collecting area is required to collect solar energy and also energy varies with time [6-8].

Recent Statistics show that the demand for energy has been constantly increasing and at this rate, even the existing reserves would not even survive the forecasted date. Thus, there is an alarming need to find alternative energy sources [9-11].

In the long term, there can be a high return on investment due to the amount of free energy a solar panel can produce, it is estimated that the average household will see 50% of their energy coming from solar panels.

Reflecting materials and its reflectivity range is shown in Table.1.

In the current paper consider the parabolic collector used as it yields higher temperatures by reflecting the sun's rays and concentrate on a single focal point here a boiler is used in order to generate the steam with aluminum foil as a reflector and aluminum foil, mirror as reflectors.

Table 1: Reflecting Materials and its Reflectivity

Materials	Reflectivity
Aluminum foil reflectivity	88% on bright side
Polished anodized aluminum	95%
Glass mirror	99%

METHODOLOGY

Experimental Work

Large steel sheets are taken and cut into 6 triangular parts. The dimensions of these parts are: two sides are of 94 cms each and the included angle is 60^0. Arcs are drawn on these parts at the radius of 94 cms and then it is cut at that curve. A total of 6 arc- shaped parts which form a perfect circle when aligned properly.

Figure 1: Triangular Piece of Steel Sheet

Now a small circle is placed at the center of the circle and another large surface is placed at a height of 27.5 cms from the ground. Then the triangular pieces are bent such that the outer arcs are in contact with the surface at the height. The pieces are also bent so that they can form a perfect dome-shaped body. It is ensured that the pieces have protruding slabs where holes are drilled. Then all the 6 pieces are fastened together to form a paraboloid in the holes drilled with the help of bolts. This paraboloid is set up on an angle variable stand to align the paraboloid in the line of sun rays. Thus it is ensured that the paraboloid meets requirements.

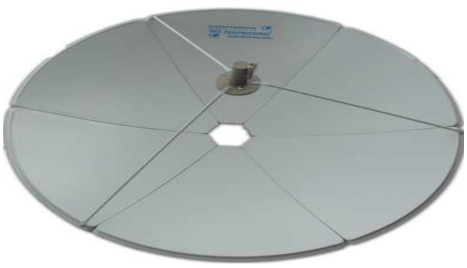

Figure 2: Triangular Pieces Assembly

Initially, a cylindrical thin sheeted stainless steel box is taken. The lid and the container are brazed together taking enough care that there cannot be any leakages. Three holes have been drilled into the box in different places for water inlet, steam outlet, and the pressure gauge. Valves have been placed in the inlet and outlet holes and pressure gauge is also

mounted. The boiler is insulated using foam and asbestos wires. Boiler setup is shown in Figure 3.

Figure 3: Boiler Set Up

Aluminum foil is used as a reflector on the paraboloid and is shown in Figure 4. Its specifications were as follows aluminum foil has the roughness of 1.12 µm. It has a thickness of 13 µm. The aluminum foil was cut into small rectangular pieces and pasted on a complete area of the paraboloid. The paraboloid is placed in line with sun rays such that the sun rays are incident on the paraboloid are parallel to its axis and the boiler is placed at the focus of the paraboloid. The total assembled experimental setup is shown in Figure 5.

Figure 4: Aluminium Foil

Figure 5: Assembled Experimental Set Up of Aluminium Reflector

Aluminum Mirror foil as reflectors on the paraboloid is shown in Figure 6. Aluminum foil has a roughness of 1.12 µm. It has a thickness of 13µm. Aluminum foil's reflectivity is 88%. The aluminum foil was cut into small rectangular pieces and pasted on only half of the area of the paraboloid. Half of the area of the paraboloid is cover with foil and the other half is covered in mirror. Small tiny mirrors of 2.5x2.5cms each were used (2307 pieces in total). The thickness of the mirrors is 3 mm. Mirror and foils are placed intermittently on the panel so that the focus of the paraboloid is not displaced from that of foil alone.

Figure 6: Assembled Experimental Set Up of Foil and Mirror Reflector

RESULTS AND DISCUSSIONS

Experimental Study of Aluminum Foil as Reflector

The pressure and temperature readings are taken at regular intervals of 15mins and observations are recorded and are tabulated in Table.2.

Table 2: Experimental Readings for Aluminum used as Reflector

S. No.	Initial Time (PM)	Final Time (PM)	Avg. Focal Point Temp. (^{o} C)	Steam Temp. (^{o} C)	Atm. Temp. (^{o} C)	Steam Pressure (bars)	Water Temp (^{o} C)
1	2:15	2:30	155	90	34	0.673	80
2	2:30	2:45	162	90	34	0.684	81
3	3:00	3:15	150	89	33	0.652	81
4	3:15	3:30	148	89	33	0.648	81

Experimental Study of Aluminum Foil with Mirror as Reflector

The pressure and temperature readings are taken at regular intervals of 15mins and observations are recorded and are tabulated in Table.3.

Table 3: Experimental Readings for Aluminium Foil and Mirror used as Reflector

S. No.	Initial Time (PM)	Final Time (PM)	Avg. Focal Point Temp. (^{o} C)	Steam Temp. (^{o} C)	Atm. Temp. (^{o} C)	Steam Pressure (bars)	Water Temp (^{o} C)
1	2:15	2:30	205	95	41	86	0.795
2	2:30	2:45	220	96	41	88	0.841
3	2:45	3:00	215	95	41	88	0.823
4	3:00	3:15	200	94	40	86	0.823

CALCULATIONS

Aluminium Foil as Reflector

Total Heat consumed

Latent Heat of evaporation of water = 2.283×10^6 J/Kg at temperature of 90^0C

Water initially =1kg, Obtained steam =0.1kg, Time taken =15min=900sec,

Specific heat of water=4185 J/kg-K,

Sensible heat (Q_{SH}) = $mc_p\Delta T$ =1x4185x (82-27) = 230175J

Latent heat (Q_{LH}) = m x (L. H) = $0.1 \times 2.283 \times 10^6$ = 228300J

Total Heat received=S.H+L.H =230175+228300 = 458475J

Power received = S.H+L.H/ Time =458475/900 = 509.41W

Heat Generated at Focus Point

Heat generated $=I_t$ x A =509.41 x 2.769 = 1410.57 J

Where I_t= Solar radiation per m^2, A=Surface area of reflection

Total System Efficiency

Efficiency=Heat consumed/Heat generated

η = (509.41/1410.57) x100 =36.11%

Aluminium Foil with Mirror used as Reflector

Heat Consumed

Latent Heat of evaporation water=$2.27x10^6$ J/kg at the temperature of 95^oC

Initially water= 1 kg, Obtained steam =0.15kg, Time taken= 15min=900 sec

Sp heat of water= 4185 J/Kg K

Sensible heat (Q_{SH}) = $mxc_px\Delta T$=1x4185x (88-27) = 255285J

Latent heat (Q_{LH}) = m x (L.H) =$0.15X2.27X10^6$ = 340500J

Heat consumed = S.H+L.H= 255285+340500= 595785J

Power consumed =S.H+L.H/Time=595785/900=661.98W

Heat Generated at Focus Point (Foil and Mirror)

Heat Generated $=I_t$ x A

Where I_t= Solar radiation per meter, A=Surface area $=A_1+A_2$

I_{t1}=Solar radiation per meter for foil, I_{t1}= reflectivity x solar radiation

=0.88x575.55=506.48 W/m^2

I_{t2}= Solar radiation per meter for mirror, I_{t2}= Reflectivity x Solar radiation

=0.98x575.55 =564.039 W/m^2

Area of Foil= 1.3845 m^2 $=A_{1,}$ Area of Mirror= 1.3845 m^2 = A_2

Total Heat Generated= (I_{t1}x A_1) + (I_{t2}x A_2)

= (506.48X1.3845) + (564.039X1.3845) = 1482.133 W

Total System Efficiency

Efficiency (η) = (Heat consumed/ Heat generated) x100

η = (661.98/1482.13)x100=44.66%

Variation of Temperature with Time

Aluminum Foil as Reflector

The variation of outlet temperature with respect to time is shown in Figure 7. With aluminum foil as reflector, a graph is drawn between temperature and time. From the graph, it is observed that as time goes on increasing temperatures increases until 14.30 p.m. and then decreases.

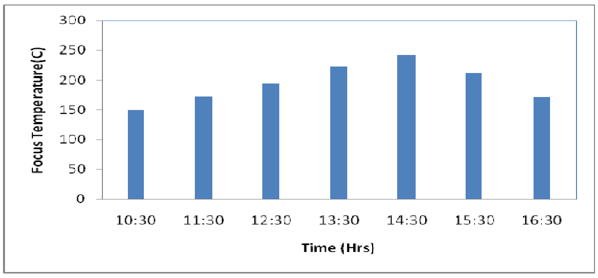

Figure 7: Variation of Temperature with Time

Aluminum Foil with Mirror as Reflector

The variation of outlet temperature with respect to time is shown in Figure 8. With aluminum foil with a mirror as reflector, a graph is drawn between temperature and time. From the graph, it is observed that as time goes on increasing temperatures increases until 14.30 p.m. and then decreases.

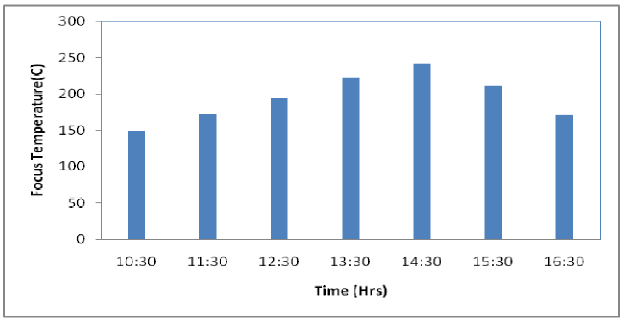

Figure 8: Graph Between Max Focus Temp and Time

Table 4: Comparison of with and without Mirror for Aluminum Foil

S. NO.	Reflector	Heat Generated (W)	Heat Consumed (W)	Efficiency (%) η	Max focus Temp (^{o}C)
1	Without Mirror	1410.58	509.41	36.11	184
2	With mirror	1482.13	661.98	44.66	281

CONCLUSIONS

Experimental investigations on the solar parabolic collector with foil and mirror are done in this study. System performance has been compared with and without a mirror in aluminum foil. It is observed that the maximum focal point temperature is about 33% more with mirror, when compared to foil without the mirror. The total system efficiency is increased by 8% for foil with the mirror when compared it with without mirror. The total heat consumption is increased by 7.6% more with a mirror when compared it with without mirror.

In this paper aluminum, foil is used as a reflector in contrast to mirror which is conventionally used so as to decrease the high costs involved when mirror is used. When mirror is used as a reflector it increases the vulnerability of the system as well thus increasing the maintenance costs as well. The heat generated by the paraboloid when aluminum, foil is used as the reflector is enough to produce steam mass cooking. However it is found that the thermal efficiency of the system is 36.11% only. To further increase the efficiency of the system mirrors for half the area of the panel, while the other half has aluminum, foil spread over it which decreases the vulnerability and initial costs by a huge margin. It is found that the efficiency of the system rises to 44.66% in this setup. Thus it can be inferred that a particular paraboloid dish can be customized to generate certain temperature at the focus for various applications by varying the extent of mirror used on the panel. Thus for a particular application the paraboloid size and reflector used can be varied to obtain the required heat and temperature.

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